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THE DEVELOPMENT AND APPLICATION OF THE MAGNETRON,(U)
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FOREIGN TECHNOLOGY DIVISION

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by

Yang Gangyi

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THE DEVELOPMENT AND APPLICATION OF THE MAGNETRON

by Yang Gangyi

The magnetron first appeared in 1921 but was only put into formal use on the eve of World War Two. At the end of 1939, to defend against sneak attacks by German aircraft and warships, Britain's radar network, set up on its east and south coasts, urgently required a high powered microwave source to replace the long wave transmitters. For this reason, they stopped tests on the cyclotron in the nuclear physics laboratory at Birmingham University and began to research the magnetron. The first experimental magnetron was trial-produced by Landeer and Bute of Britain. This magnetron had three mercury pumps which continually pumped gas; its wavelength was 9.8 centimeters and its pulse output power was about 400 watts. This was the prototype of the modern magnetron. At the time, the British government was encountering many difficulties because of the war and thus, in order to provide the armed forces with the magnetron as quickly as possible, they began to set up a cooperative relationship with the United States. Finally, in 1940 the Bell Telephone Company of the United States successfully manufactured a sealed magnetron with a wavelength of 10 centimeters and a pulse power of 10 kilowatts. Both the frequency and power of this magnetron were several times greater than the triodes of that time. Thus, it became the microwave power source of the radar transmitters for defense against aircraft and warships, as well as the power source with the largest power, highest frequency, smallest volume, and lowest cost used for radar on aircraft carriers.

The war greatly stimulated the rapid development of the magnetron. In 1944, a magnetron with a 10 centimeter wave band had a pulse power which reached to 2 megawatts. It seems that all radar was using magnetron transmitters. Because of this, the production quantity of magnetrons during World War Two was quite large. After this, various new models of magnetrons such as the voltage tuning magnetron, coaxial, reverse coaxial and fast speed tuning magnetrons successively appeared.

After the 1960's, following the electronic confrontation of modern warfare, the use of the magnetron in military affairs was replaced by the travelling wave tube and other microwave devices and so its sphere of application diminished. However, after the appearance of the direct heat type thorium tungsten cathode continuous wave magnetron in 1958 and the rise of microwave heating technology, the magnetron entered a new stage of development whereby it was used by the military and gradually for civilian use.

In recent years, the development of magnetron research and manufacturing technology has been dominated by application and two trends have become prominent. In order for it to be continuously used in a new radar system, they actively developed a fast changing frequency electric tuning magnetron. On the other hand, they made every effort to develop the use of a continuous wave magnetron in microwave heating technology.

Use in Radar

Its most widespread use in the present or for the future, aside from microwave heating, still has its greatest potential in airborne, ship, weather, harbor control and some moveable ground tactic radar. The use of the magnetron is especially appropriate for airborne radar. Prior to the appearance of the

magnetron, the first airborne radar used metric wave band tricode transmitters. For example, the "Light Ruby" interceptor radar which was fitted on the German's Junker-88 aircraft had a wavelength of 2 to 3 meters and a pulse power of only 2.5 kilowatts. When used at a close distance, its resolution was low and it fell far short of the magnetron transmitter. Modern aircraft fly at high speeds and high altitudes, and are quite large. In order for an aircraft to have a safe and dependable flight as well as be able to accurately locate targets at the proper time, aircraft are usually equipped with one or several sets of radar. There are many types of airborne radar. For example, gunfire control radar, search radar, weather radar, ground mapping radar, Doppler navigational radar and radar range finders all use magnetrons in their transmitters. Because the magnetron has high efficiency, has low voltage, is light in weight, is small in volume, has sufficiently high power, is low in cost and its use and maintenance are convenient, it suits the small size, light-weight and high resolution requirements of airborne radar. Usually, pulse magnetrons with 5,3 and 2 centimeter wavelengths and several tens to several hundred kilowatt pulse power are used. For example, America's Boeing 707 aircraft is equipped with two sets of radar. One is weather radar which uses a 3 centimeter, 75 kilowatt coaxial magnetron (as shown in fig. 1). The other is pulse Doppler navigational radar which uses a 2 centimeter, 40 watt beacon magnetron. Furthermore, there is also a type of airborne single pulse gunfire control radar manufactured by the Marconi Company of Great Britain which uses a 3 centimeter, 180 kilowatt magnetron.

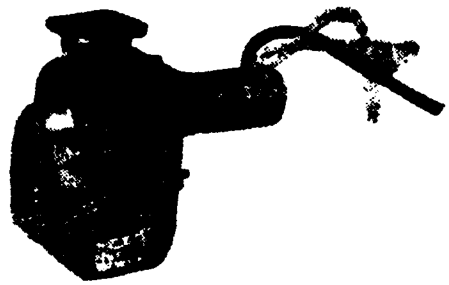

Fig. 1 Airborne Weather Radar Which Uses a 3 Centimeter, 75 Kilowatt Coaxial Magnetron

Aside from airborne radar, ground air radar systems also make great use of magnetron transmitters. For example, air traffic control radar distinguishes even more and further target aircraft, and only requires several megawatt powered magnetrons. When used in airfield air surveillance and airfield control radar, in order to attain even higher resolution and distinguish targets such as runways and beacon lights, then magnetrons with shorter wavelengths of 3 and 2 centimeters and 8 millimeter wave bands are used.

Besides being used in most fields of aeronautical technology, a small powered magnetron with high frequency stabilization and short waves is used in beacon radar for guided missile flights and space technology. For example, the beacon transmitter in the American Apollo lunar capsule and control capsule used microwave magnetrons.

Microwave Heating

The widest range of use of the magnetron is for microwave heating. The power source of microwave heating is a continuous wave magnetron. At present, the production of this type of

magnetron makes up over 80 percent of all magnetrons produced.

Microwave heating technology first appeared in 1945. When Sifansai of the United States made his first radar test, he accidentally discovered that a piece of candy in his pocket melted and from this he came to the understanding that microwaves had an excellent heating effect on a medium. Soon after, he invented the microwave oven for household use which could bake food. Yet, only during the late 1960's did a microwave oven with an inverse structure (as shown in fig. 2) appear and begin to be widely used.

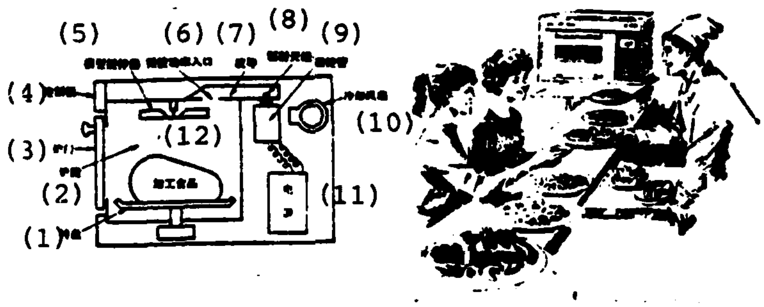

Fig. 2 Inner Structure and External View of the Microwave Oven

Key:
1. Turning plate
2. Oven chamber
3. Oven door
4. Control panel
5. Model agitator
6. Microwave power entrance
7. Wave guide
8. Radiation antenna
9. Magnetron
10. Cooling fan
11. Power source
12. Processed food

Up until today, there have been three main areas in which microwave heating has been used: microwave ovens for household

use, industrial and agricultural production and medicine. Among these, the microwave ovens for household use have the largest market. Its use in households in the United States, Japan and countries in Northern Europe has been daily expanding and its rate of popularization is already 25 percent. Thus it is gradually replacing the traditional household electric and gas stoves. In 1978, the total production of microwave ovens for household use was 4 million. The magnetron used in the microwave ovens for household use work at 2,450 megacycles, the power is from 500 to 1,500 watts, and the variety of microwave products has reached to several hundred types, thus offering consumers free choice. The price is from 200 American dollars for a low grade oven to over 700 American dollars for a high grade model. The high grade model is fully equipped with a microprocessor sequence control so that the sequence of the oven's power, time and temperature can be prearranged. Because the microwave oven is convenient, safe and reliable, processes good quality food, and uses only one third the electricity of a common electric stove, it is becoming more and more well received by consumers.

The use of microwave heating in industrial and agricultural production is gradually spreading. Because microwaves heat an item quickly, evenly, without heat inertia, with high heat efficiency, low surrounding temperatures, they are gradually replacing the traditional drying room, hot air and ultraviolet radiation methods. The magnetron used in industrial and agricultural microwave heating is 2,450 megacycles with a power of 1.6 to 5.5 kilowatts; and 915 megacycles with a power of 30 to 60 kilowatts (see fig. 3).

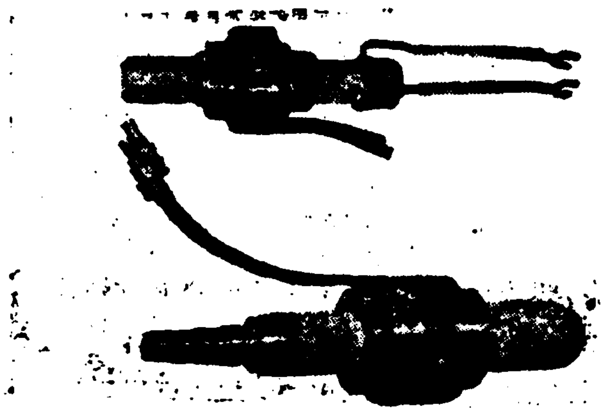

Fig. 3 Magnetrons Used in Industrial Microwave Heating; Top Magnetrons: 2,450 Megacycles With a Power of 5 Kilowatts; Bottom Magnetrons: 915 Megacycles With a Power of 30 Kilowatts

At present, the total power of the microwave heating equipment used for industrial production in foreign countries has reached to 10 megawatts. The United States and Japan make up over 80 percent of this figure with an average yearly growth speed of 1 megawatt. Its main use is in the food industry and the total power used for food sterilization, heating and drying is about 60 to 70 percent. The rest of the power is used for film drying, drug sterilization, straw mattress disinfecting, rubber vulcanization, timber drying, lacquerware and tobacco drying, and mold releasing. Aside from these, tests are being carried out on the use of microwaves to smash rock, heat plasma, for integrated circuit dry etching, raw coal desulphurization as well as microwave chemical reactions. Because the use of microwaves has still not reached a totally mature level in industry, the cost of products will possibly rise. Furthermore, because there are still difficulties in the commercialization of complete sets of microwave heating equipment, the growth speed will not meet the home use of microwave ovens. Yet, following the expansion of the range of uses of and the

increasing research on heating technology, there will be great developments of the potentials of industrial microwave heating.

Another area of future use for microwaves is that of medicine. The power of the magnetron used is from several tens of watts to several hundred watts. Microwave physiotherapy has been used in clinical practice for the fast cure of arthritis, rheumatism and the subsidence of swelling. Therapeutic results have been excellent. In recent years, research on using microwaves to kill cancerous tissue cells has advanced rapidly. Not only did the tests done on small animals show obvious effects but tests have also been done on humans. One method of microwave treatment of cancer is heat therapy. The microwaves used possess the special characteristics of selected and concentrated heat which causes the cancerous area to easily rise to 43 to 45 degrees centigrade. Under this temperature, the cancer cells are destroyed. Heat therapy can also be combined with chemical therapy or radiation therapy so that the effectiveness of chemical therapy or radiation therapy is greatly strengthened. This field of research is getting more and more attention. It can be predicted that microwaves will be able to make a great contribution to overcoming cancer, the very serious threat to human life.